PARKER, R. O., JR. and STEVE W. ROSS. 1986. Observing reef fishes from submersibles off North Carolina. Northeast Gulf Science 8(1): 31-49.

Northeast Gulf Science Vol. 8, No. 1 March 1986 p. 31-49

OBSERVING REEF FISHES FROM SUBMERSIBLES OFF NORTH CAROLINA

R.O. Parker, Jr.
Southeast Fisheries Center
Beaufort Laboratory
National Marine Fisheries Service
NOAA, Beaufort, NC 28516-9722
and
Steve W. Ross[1]
North Carolina Division of Marine Fisheries
P.O. Box 769
Morehead City, NC 28557

ABSTRACT: During August and September 1979, the submersibles JOHNSON SEA LINK-II and NEKTON GAMMA were used to observe fishes at 13 reefs in Raleigh, Onslow, and Long Bays, N.C., at depths ranging from 23 to 152 m. Reefs with the highest profile (up to 10 m) and in depths of 52 to 92 m exhibited the greatest fish species richness and abundance, while adjacent sandy areas were usually barren of fishes. Estimates of recreationally and commercially important reef fishes were 61/ha (S.E. 59.9) over sand and 774/ha (S.E. 748.1) over reefs, with considerable variation between stations. Ninety-nine species in 35 families were observed. Most numerous were Holocentridae, Serranidae, Priacanthidae, Haemulidae, Sparidae, Sciaenidae, Chaetodontidae, Pomacentridae, and Labridae. Many tropical species previously thought to be rare off North Carolina were abundant.

Traditional surface deployed fishing gears are unsatisfactory for determining the structure and composition of most reef fish communities. Although hook and line and traps are inexpensive and easily deployed in most depths and on rough bottoms, their catches do not always represent the fish populations present. Estimates of abundance or composition often are biased by gear selectivity for certain size classes, species behavior, area sampled, and other factors. Specially rigged trawls can be towed over some reefs to obtain quantitative data, but they are not effective for capturing cryptic or large individuals, and they damage reefs (Wenner 1983). None of these gears permit precise information on fish behavior, habitat utilization, or faunal composition.

Still and motion photographic techniques both by divers (Smith and Tyler 1973a; Alevizon and Brooks 1975; Ebeling *et al.* 1980) and from surface ships (Powles and Barans 1980) have been employed to observe reef fishes. Photographic methods allow a permanent record of extended observations on fish behavior and habitat association, but have only limited use because of inadequate lighting, small depth-of-field, narrow angle of view, and difficulty in tracking target objects. Surface-deployed cameras requiring umbilical cords have additional problems related to ship stability and control of camera view. Accoustic monitoring (Barans and Holliday 1983) has many of the same problems, in addition to validation of the technique.

Since the early efforts of Brock (1954) there has been increasing use and support of *in situ* visual assessment of reef fish communities using SCUBA gear (Helfman 1983). A wide variety of techniques for both qualitative and quantitative data collection on abundance, biomass, and behavior have been employed. Most of these studies were in

[1]Present Address: Zoology Dept., North Carolina State Univ., Raleigh, N.C. 27695

clear, shallow, tropical marine waters (e.g. Starck 1968; Collette and Talbot 1972; Smith and Tyler 1973b; Emery 1973; Luckhurst and Luckhurst 1978; Jones and Thompson 1978; Willan *et al.* 1979; Bohnsack 1982). More recently many of the same techniques have been applied in temperate marine waters of the southeastern United States (Smith 1976; Hastings *et al.* 1976; Hastings 1979; Parker *et al.* 1979).

Submersibles, which enable observers to dive more deeply and to stay underwater longer than SCUBA, have begun to play an increasingly important role in reef fish assessment. They have been used in the Gulf of Mexico (Bright and Pequegnat 1974; Shipp and Hopkins 1978), Caribbean (Colin 1974), Bahamas (Colin 1976), off the east coast of Florida (Gilmore 1977; Reed and Gilmore 1981), and New England (Grimes *et al.* 1982a). We used submersibles to observe the deep water ichthyofauna of rock, coral, and sponge reefs off North Carolina. Our objectives were to 1) estimate standing stocks to supplement our yield estimates of reef fishes important to recreational and commercial fisheries, 2) examine the effect of submersibles on fish behavior, 3) estimate species composition and relative abundance, and 4) observe behavior and habitat utilization on reefs below SCUBA depths.

METHODS

We used two submersibles during August and September 1979. The JOHNSON-SEA-LINK-II (Harbor Branch Foundation, Inc., Ft. Pierce, FL 33450) (Fike and Dolan 1976), used for 10 dives, carried a pilot, tender, and two observers. The NEKTON GAMMA (General Oceanographics, Inc., San Diego, CA 92121) (Uzmann *et al.* 1977), used for 7 dives, carried one operator and one observer.

During almost 23 h of dive time, at depths from 23 to 152 m, we examined 11 reefs in Onslow Bay, one in Raleigh Bay, and one in Long Bay (Fig. 1). Stations were selected to ensure that a variety of depths and reef types were included. Time, depth, bottom water temperature, habitat characteristics, biological observations, and the submersible's position were recorded frequently.

Transect distances and horizontal visibility were measured so that we could relate numbers of fish to units of area. Loran C aboard surface support ships was used to determine transect length and position. At the beginning of each dive, the JOHNSON-SEA-LINK-II would back away from a "secchi disk" placed on the bottom (Fig. 2) until it faded from view. The distance to fade-out, or horizontal visibility, was determined with a measuring wheel attached to the bow of the submersible. As the submersible followed a straight compass course across a reef the forward observer recorded on tape and film habitat type, fish behavior, species composition, and relative abundance of all species. At the same time from the starboard porthole, the aft observer counted recreationally and commercially important fishes (Huntsman 1976) within his view, 90° to the transect path. From horizontal visibility and distance traveled a rectangular area was calculated. This area was later reduced to ¾, since in previous experiments using SCUBA the senior author observed that fishes faded from view in the last quarter of an observer's visibility range. Procedures with the NEKTON GAMMA were similar, except that horizontal visibility had to be estimated because this submersible did not have a measuring wheel or "secchi disk", and the single observer had to perform all scientific operations and

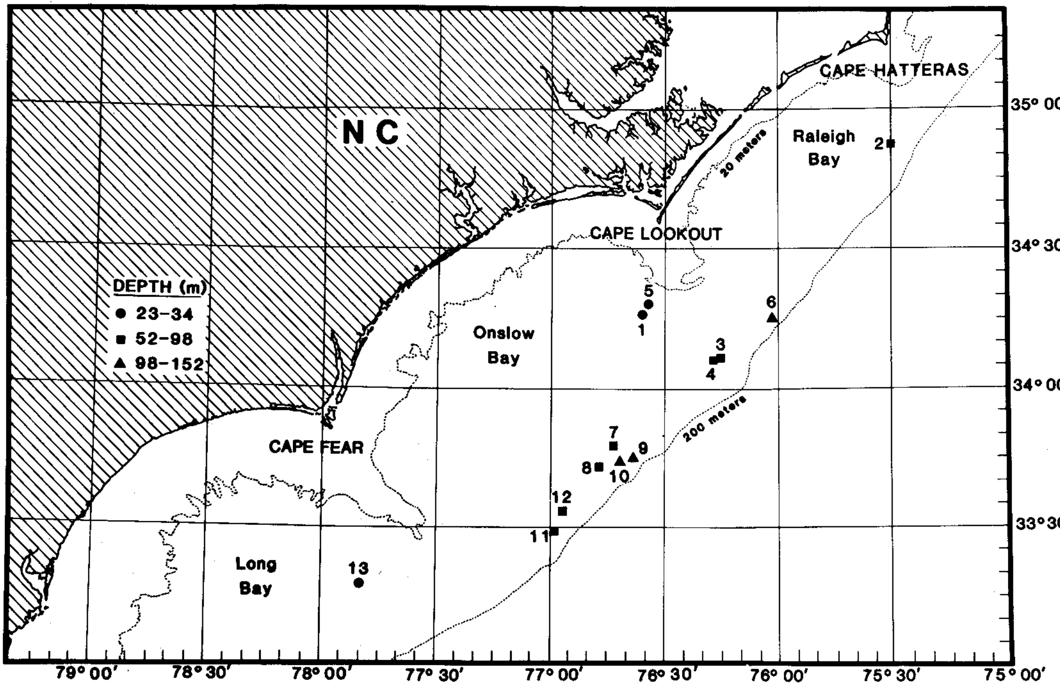

Figure 1. Submersible station location and relative depth in Raleigh, Onslow, and Long Bays, N.C., during August and September 1979.

observations.

On two occasions we compared observations made from a submersible to those made by SCUBA divers to determine 1) if submersibles altered behavior of reef fishes beyond that caused by SCUBA divers, and 2) if estimates from submersibles of abundance of reef fishes important in the recreational and commercial fisheries can be compared to those made by divers. On 6 August divers counted fishes and observed fish behavior in a 360° area during passage of the JOHNSON-SEA-LINK-II at two locations along a 180 m transect at station 1 in depths of 27 to 29m (Fig. 3). Location centers on the transect were 60 m apart and were marked with surface buoys. Each location center was the focus of a circular area 30 m in diameter (707 m^2). A pair of divers measured lateral visibility at each location with a "secchi disk" and then marked the limits of visibility on the transect with buoys 1 m

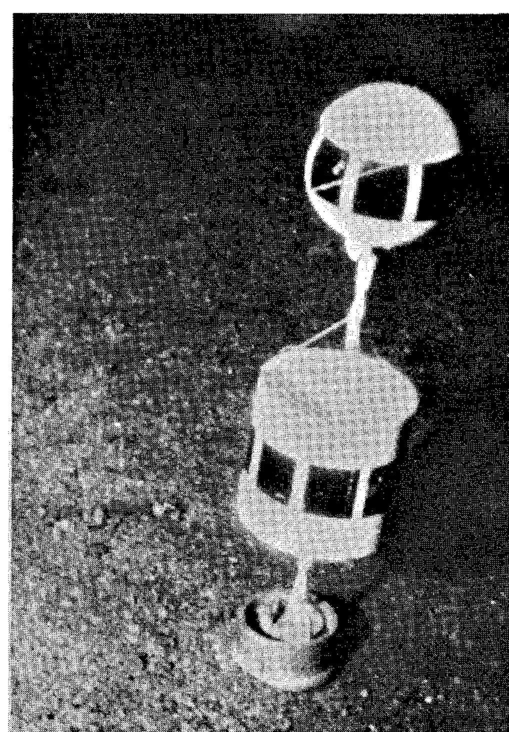

Figure 2. Buoyed "secchi disk" used to measure depth-of-field from the JOHNSON-SEA-LINK-II.

above the reef. One end of the transect, 60 m from the first location, was marked with a signaling device to indicate the submersible's starting point. The submersible cruised along the transect line and the aft observer counted fishes on the starboard side between the location limit markers. The rectangular area (450 m^2) observed from the submersible overlapped the circular area observed by the SCUBA team and was approximately ⅔ as large. It was made to overlap the circular area so that the counts could be compared to those of the SCUBA divers. Another comparison was made during a 26 min transect run by the JOHNSON-SEA-LINK-II on 7 August in the same general area. Fishes were counted and behavior was noted in the same way as on 6 August. Fifteen minutes later two SCUBA divers recorded species composition and abundance during a 25 min dive.

RESULTS

Ninety-nine species of fishes representing 35 families were observed (Table 1). At most sites, tropical and subtropical species belonging to the families Holocentridae, Serranidae, Priacanthidae, Haemulidae, Sparidae, Sciaenidae, Chaetodontidae, Pomacentridae, and Labridae dominated the ichthyofauna in either numbers of species, numbers of individuals, or both. Subtropical species (e.g., spotted moray, *Gymnothorax moringa*, vermilion snapper, *Rhomboplites aurorubens*, spotfin butterflyfish, *Chaetodon ocellatus*, blue angelfish, *Holacanthus bermudensis*, slippery dick, *Halichoeres bivittatus*, sharpnose puffer, *Canthigaster rostrata*), were the most numerous reef fishes at all depths. The shallowest stations (1, 5, 13) contained more temperate species, such as black sea bass, *Centropristis*

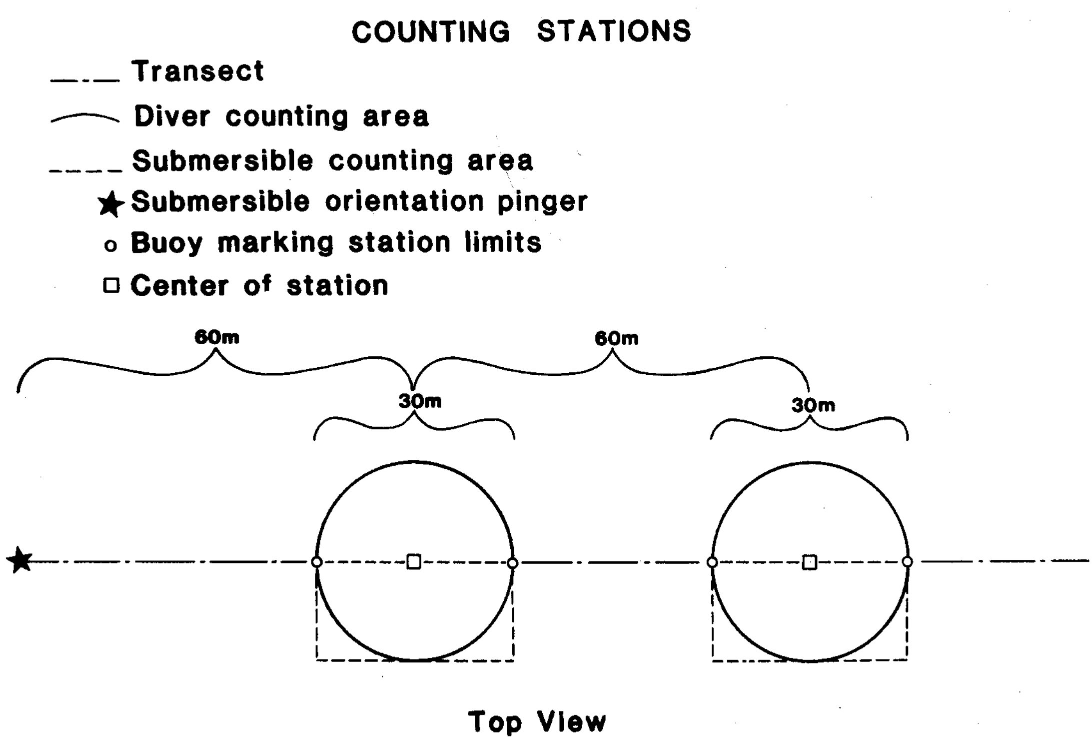

Figure 3. Submersible and SCUBA diver fish counting stations on 6 August 1979 at station 1.

Table 1. Number of stations at which species were observed from submersibles in each depth stratum during dives in August and September 1979. The number of stations per stratum is in parentheses.

Family and species	Depth strata (m)		
	23-34, (3)	52-98, (7)	98-152, (3)
Dasyatidae			
Dasyatis sp.		1	
Muraenidae			
Gymnothorax moringa		2	
G. saxicola		1	
Muraena retifera			2
M. robusta		2	
Congridae			
Conger sp. or *Paraconger caudilimbatus*		2	1
Ophichthidae			
Myrichthys acuminatus		1	
Synodontidae			
Synodus sp.		1	
Batrachoididae			
Opsanus sp.[1]	1		
Ogcocephalidae			
Ogcocephalus sp.			2
Holocentridae			
Holocentrus ascensionis	1	6	
Syngnathidae			
Hippocampus erectus		1	
Serranidae			
Centropristis ocyurus	3	4	
C. striata	3	1	
Diplectrum formosum	1	1	1
Epinephelus adscensionis		1	
E. cruentatum		2	1
E. drummondhayi		2	2
E. flavolimbatus	1		
E. morio			1
E. mystacinus			1
E. nigritus		2	
E. niveatus		4	2
Hemanthias vivanus		6	3
Holanthias martinicensis		3	3
Liopropoma eukrines	2	5	2
Mycteroperca interstitialis		1	
M. microlepis	3	6	
M. phenax	2	5	
M. venenosa	1		
Paranthias furcifer		3	
Serranus phoebe	2	7	3
S. subligarius	2		
S. tigrinus	1		
Grammistidae			
Rypticus maculatus	1	1	

Table 1 (Continued)

Priacanthidae			
Priacanthus arenatus	1	7	2
Pristigenys alta	1	3	1
Apogonidae			
Apogon pseudomaculatus		3	
Malacanthidae			
Caulolatilus microps		2	1
Carangidae			
Caranx bartholomaei	1	1	2
C. c.f. crysos		1	
Decapterus punctatus	1		
Seriola dumerili	1	3	3
S. rivoliana		2	1
Lutjanidae			
Lutjanus campechanus	2	2	
L. vivanus			1
Rhomboplites aurorubens		4	1
Haemulidae			
Haemulon aurolineatum	1	1	
H. plumieri	2	1	1
H. striatum		2	1
Sparidae			
Calamus leucosteus	1		
C. nodosus	1	1	
Diplodus holbrooki	2		
Pagrus pagrus	1	1	1
Stenotomus caprinus	1	2	
Sciaenidae			
Equetus lanceolatus	1	3	
Pareques umbrosus	3	3	1
P. sp. (black bar)[2]		2	2
Mullidae			
Pseudupeneus maculatus	1	1	
Chaetodontidae			
Chaetodon aya		3	2
C. ocellatus	1	2	1
C. sedentarius	1	5	1
C. striatus	1	1	
Pomacanthidae			
Holacanthus bermudensis	2	5	1
H. ciliaris	1	2	
H. tricolor	1	3	
Pomacanthus arcuatus		1	
P. paru		1	
Pomacentridae			
Chromis enchrysurus	3	7	1
C. insolatus		2	
C. scotti	3	4	
Eupomacentrus partitus	2	2	
E. planifrons		1	

Table 1 (Continued)

Labridae			
Bodianus pulchellus	1	5	
B. rufus		2	
Decodon c.f. *puellaris*		4	1
Halichoeres bivittatus	3	2	
H. caudalis	1	1	
H. garnoti	2	1	
H. maculipinna		1	
Hemipteronotus novacula		1	
Lachnolaimus maximus	1	3	
Thalassoma bifasciatum	2		
Sphyraenidae			
Sphyraena barracuda	1		
Blennidae			
Parablennius marmoreus	1	1	
Gobiidae			
Ioglossus calliurus	1	1	
Acanthuridae			
Acanthurus chirurgus	1	1	
A. coeruleus			1
Scombridae			
Euthynnus alletteratus		1	
Scomber sp.		1	
Scomberomorus cavalla	1		
Scorpaenidae			
Scorpaena sp.		2	1
Triglidae			
Unidentified		1	
Balistidae			
Balistes capriscus	2	2	
Monacanthus sp.		1	
Ostraciidae			
Lactophrys sp.		4	
Tetradontidae			
Canthigaster rostrata		2	
Sphoeroides spengleri		1	
Diodontidae			
Chilomycterus sp.		1	
Molidae			
Mola mola		1	
Total Species	50	83	34

[1]*Opsanus sp.* is an undescribed form.

[2]An undescribed species of *Pareques* termed blackbar by G.C. Miller, NMFS, Southeast Fisheries Center, Miami, FL 33149, pers. commun. (1980)

striata, and longspine porgy, *Stenotomus caprinus*.

Although most fishes occupied a wide depth range, certain species appeared to characterize particular depth strata. If stations were grouped into three depth categories, 23 to 34 m, 52 to 98 m, and 98 to 152 m (Table 2), based on species assemblages (Table 1), the hypothesis that the average number of species per station was the same in all three categories was rejected by analysis of variance ($p < 0.05$). At all depths, reefs with the highest profile (up to 10 m) appeared to have the largest number of species and individuals. Sandy areas near the reefs were noticeably barren, regardless of depth. We found the greatest number of species in the middle depth interval, 52 to 98 m, (Table 2) where stations 3, 8, and 11 had the highest number of species. Excluding station 7 (sampled at night) and station 12 (sparse, low profile habitat), the mean number of species per station in this stratum was 34.

Fish Abundance

About 13 h were spent in the submersibles estimating abundance of reef fishes important in the North Carolina recreational and commercial fisheries (Table 3). Over 30 ha were surveyed along 14 transects that took from 14 to 117 min to complete. Only 7% of the fishes counted were observed over sand, although 32% of transect time was over sand because 1) reefs are distri-

Table 2. Reef fish family and species richness, and abundance of species important in the North Carolina recreational and commercial fisheries (Table 3), by station and depth, observed from submersibles during dives in August and September 1979.

Station	Depth (m)	Observation time (min)	Visibility (m)	Bottom water temp. c°	Number Families	Number Species	Number Fish/ha
5	23-24	90	14[a]	24.5	14	27	b
1	27-29	51	15	22.3	12	20	121
13	28-34	84	15[a]	26.5	12	31	52
Total	23-25	225			20	51	173
Average			14.7	24.4	13	26	87
11	58-64	117	14[a]	22.0	22	43	31
4[c]	52-66	189	30-39	18.0-19.0	11	29	37,4,6
7	67-70	65	10[a,e]	21.5	9	11	6
2[d]	53-75	198	19-30	19.0-19.5	10	25	4,4
12	79-84	95	35[a]	18.0	12	18	1
3	73-95	190	24-25	19.4-21.3	17	38	3
8	79-98	99	29[a]	19.5	15	37	9
Total	52-98	903			33	91	105
Average			24.5	19.7	14	29	15
10	98-101	51	30[a]	21.5	10	17	2
9	125-137	69	11[a]	16.0	10	16	8254
6	116-152	125	10[e]	17.0	9	18	f
Total	98-152	245			17	34	8256
Average			17	18.2	10	17	4128

[a]Visibility estimated by pilot.
[b]Did not associate fish with type of bottom.
[c]Three transect counts made at this station.
[d]Two transect counts made at this station.
[e]Visibility limited to headlight penetration.
[f]No counts made because fish overtook slow-moving submersible.

Table 3. Numbers of reef fishes per hectare important in the North Carolina recreational and commercial fisheries observed from submersibles during dives in August and September 1979.

Species	Station 1	2[a]	3	4[b]	7	8	9	10	11	12	13	Total
Centropristis striata (black sea bass)	7	2,1									2	12
Mycteroperca microlepis (gag)	16	0,1		19,2,1		1			2	1c	7	49
Mycteroperca phenax (scamp)		0,1		10,2,1		3			6		27	50
Mycteroperca interstitialis (yellowmouth grouper)									1			1
Mycteroperca venenosa (yellowfin grouper)											4	4
Epinephelus niveatus (snowy grouper)			1			1	7937 24c			1		7940
Epinephelus drummondhayi (speckled hind)		2,0					79	1				82
Epinephelus morio (red grouper)						3						3
Epinephelus nigritus (warsaw grouper)									1			1
Epinephelus adscensionis (rock hind)									5			5
Lutjanus campechanus (red snapper)			1	8,0,0							2	11
Lutjanus vivanus (silk snapper)							36c					
Rhomboplites aurorubens (vermilion snapper)		2,0		0,0,4	6							12
Pagrus pagrus (red porgy)	84						600c		1			85
Calamus nodosus (knobbed porgy)											4	4
Haemulon plumieri (white grunt)	21							1	4		3	29
Balistes capriscus (gray triggerfish)		0,2	1						2c		3	6
Caulolatilus microps (gray tilefish)							238					238
Lachnolaimus maximus (hogfish)					1				11 6c		2	14
Total	128	6,5	3	37,4,6	6	9	8254	2	31	1	54	8546

[a]Two transects counts
[b]Three transects counts
[c]Seen over sand. Not included in totals.

buted in patches over the sand bottom, and 2) ridges up to 20 m high near reefs, that appeared as reef habitat on fathometer recordings were sand mounds. Considerable variation in abundance was observed between stations. Almost all (99%) of the reef fish observed over sand were at station 9, where red porgy, *Pagrus pagrus*, (extrapolated to 660/ha), silk snapper, *Lutjanus vivanus*, (36/ha) and snowy grouper, *Epinephelus niveatus*, (24/ha) were observed rooting in the sand, and where an extraordinarily large number of snowy grouper (almost 8,000/ha), a large number of blueline tilefish, *Caulolatilus microps*, (238/ha) and speckled hind, *Epinephelus drummondhayi*, (79/ha) were observed over the reef. The average number of recreationally and commercially important reef fishes per hectare for all stations (Table 3) was 61 (S.E. 59.9) over sand and 774 (S.E. 748.1) over reefs.

Submersible - Diver Comparisons

On 6 August at both locations on the transect the SCUBA teams consistently counted more individuals of most species than the submersible observer (Table 4). The number of grouper per hectare counted from the submersible was 65% and 63% of the diver counts. Although the submersible did ellicit some localized movements, such as small species moving out of its path or retreating among the rocks, it did not seem to overly concentrate or disperse fishes into or out of the field of view. Exceptions were gag and especially greater amberjack that at times seemed to be alternately attracted to and repelled by the submersible. Most fishes appeared to treat the submersible as they did the SCUBA divers; they seemingly ignored both.

In the same area on 7 August 21 species of fish were observed from the submersible compared to 28 species by SCUBA divers. Actual numbers could be compared for 4 species. The submersible observer recorded 13 gag and no scamp, *Mycteroperca phenax*, whereas SCUBA divers counted between 40 and 50 gag and 1 scamp. In contrast, 4 red porgy and 17 whitebone porgy, *Calamus leucosteus*, were recorded from the submersible but none were seen by divers. Because the submersible covered more area, observers recorded more of the large, less frequently encountered species. The SCUBA team was more mobile in a small area and had a wider field of view, which allowed it to observe and identify small and partially hidden species better.

Habitat Observations

Reefs were composed primarily of bioeroded rocks of limestone or carbonate sediments and exhibited vertical relief ranging from < 0.5 to over 10 m. Many were ledge systems formed by rock outcrops (stations 1, 3, 4, 5, 6, 11, 13) while others were composed of piles of irregularly sized boulders (stations 2, 7, 8, 9, 10, 12). Depending on depth, rocks were usually heavily encrusted by macroalgae (depths <37 m), hydroids, crinoids, horny corals (*Lophogorgia*, *Cirrhipathes*, *Titanideum*), hard corals (*Solenastrea*, *Madrepora*, *Oculina*), and sponges (Fig. 4). Debris that seemed to be composed of rock fragments and crustose algae littered the

Table 4. Number of reef fishes, by species and location, counted from a submersible and by SCUBA divers, on 6 August 1979.

Location	Species	Submersible		SCUBA	
		actual	per hectare	actual	per hectare
1	Mycteroperca microlepis	18	28[a]	40-45	43
	M. phenax	3		0	
	Calamus nodosus	1		0	
	Balistes capriscus	0		2	
2	M. microlepis	12	17[a]	23-28	27[a]
	M. phenax	1		1	

[a]Species combined for count comparisons because they are difficult to tell apart when counted rapidly.

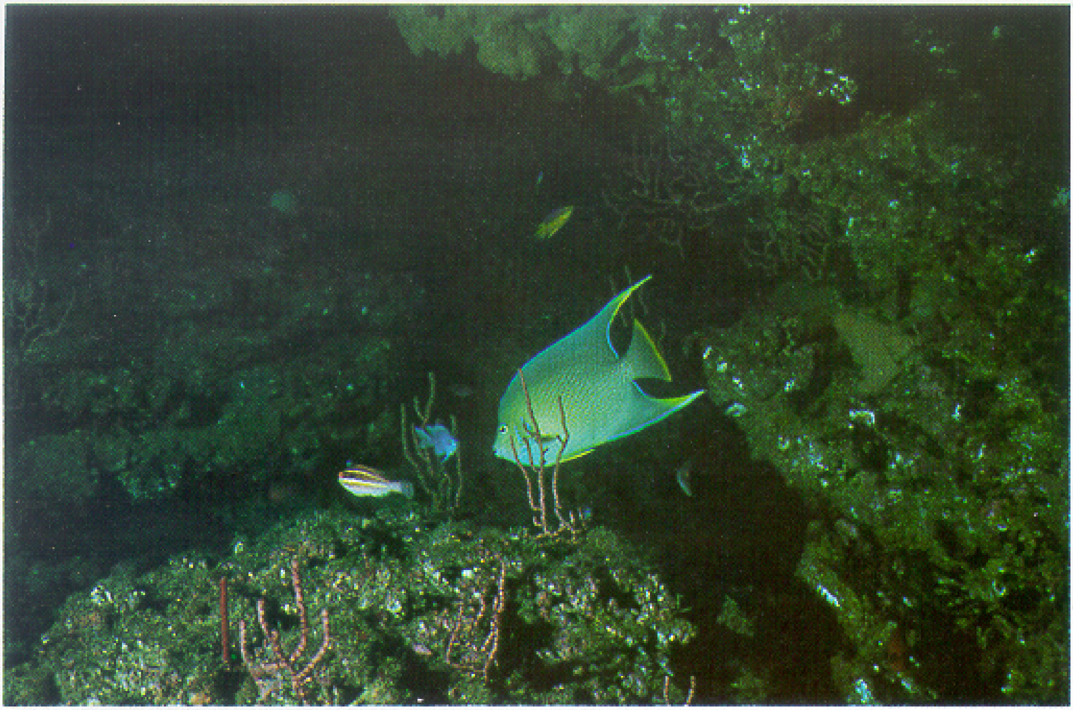

Figure 4. High profile reef (station 1) exhibiting bioeroded substrate heavily encrusted with algae, hydroids, horny corals, and sponges, 5 November 1975. Fishes in center of photo are a blue angelfish, *Holacanthus bermudensis*, Spanish hogfish, *Bodianus rufus*, striped parrotfish, *Scarus iserti*, and a purple reef-fish, *Chromis scotti*.

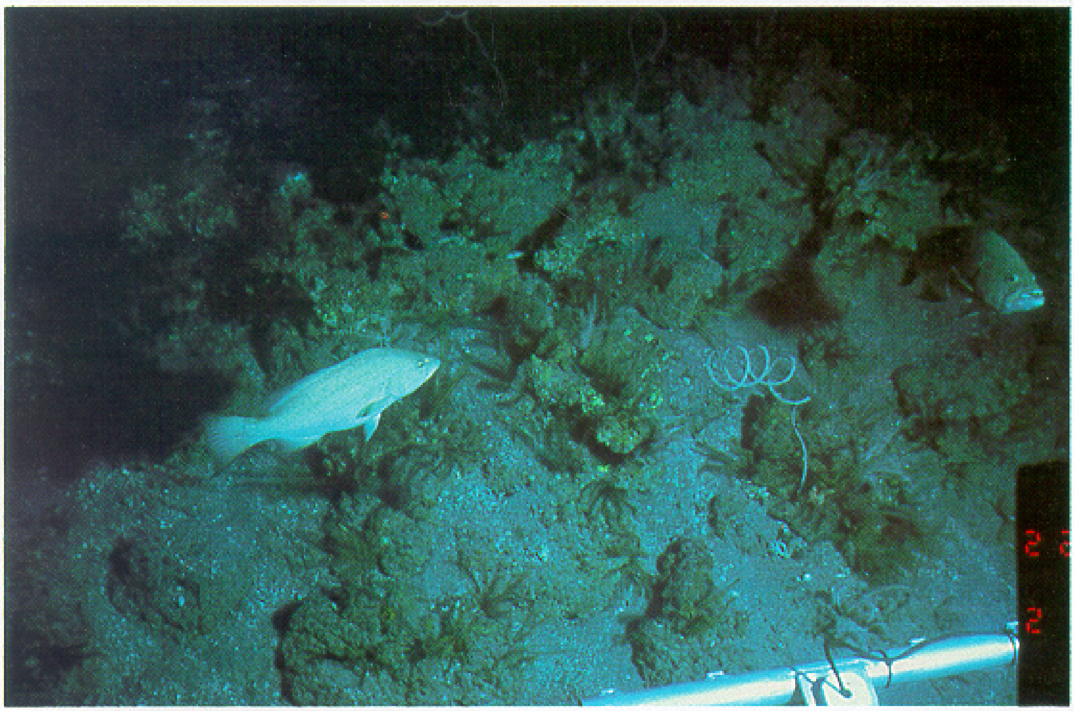

Figure 5. Scamp over rock outcropping (Station 4 — "Big Rock") sparsely encrusted with invertebrates at a depth of 100 m.

sand surrounding many reefs and boulders. Reefs in deeper water (>85 m) generally had fewer attached organisms (Fig. 5).

At stations between 34 and 98 m a distinct group of fishes was noted where small, often flat rocks were scattered in the sand around the main reef. These "islands", usually less than 1 m^2 in area, were encrusted with crinoids, sponges, and horny corals, and had a burrow or cave in the sand under one side. Burrows were generally on only one side of the rocks and appeared to be deep. We presume fish had created and maintained them. Had they been created by currents undercutting the rock, they would have occurred broadly on all exposed sides. Although one to three adult yellowtail reeffish, *Chromis enchrysurus*, were usually hovering 50 to 80 cm above the rock (Fig. 6), we never saw them enter the burrows. Typically one or two short bigeye, *Pristigenys alta*, or squirrelfish, *Holocentrus ascensionis*, were positioned in front of the burrows and retreated into them as the submersible approached (Fig. 6); however, the two species were rarely present together. On one occasion, red barbier, *Hemanthias vivanus*, sand perch, *Diplectrum formosum*, and wrasse bass, *Liopropoma eukrines*, all used the same burrow. On another occasion, a snowy grouper, blueline tilefish, and short bigeye entered the same burrow. This multiple occupancy of a single burrow was apparently encouraged by the closeness of the submersible. Tattler, *Serranus phoebe*, was also occasionally observed near the burrow systems.

Slightly different burrows, usually some distance from the main reefs, existed under rocks that lay in a depression surrounded by sand (Fig. 7). Fishes behaved as described above. Sand around the depressions usually exhibited ripple marks, indicating currents, but

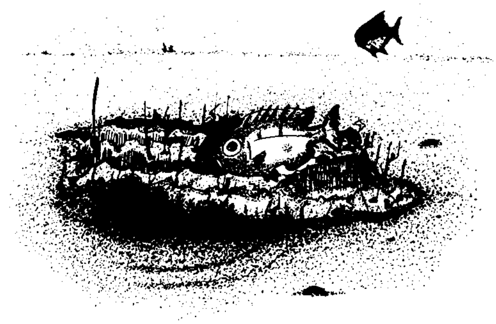

Figure 6. Short bigeye, *Pristigenys alta*, in front of a burrow and a yellowtail reeffish, *Chromis enchrysurus*, hovering above rock.

Figure 7. A typical burrow away from the main reef under a rock in a depression surrounded by sand.

ripples were absent within the depressions, possibly because they were below the current influence.

Fish Observations

Muraenidae. We found four species of moray eels (Table 1), all hiding beneath ledges or within crevices mostly between 52-76 m. Stout moray, *Muraena robusta*, appeared to be most abundant (Bohlke and Ross 1981).

Ophichthidae. One goldspotted eel, *Myrichthys acuminatus*, was observed moving along a flat part of the reef at station 11. Features aiding the identification by microscopic examination of photographs were: rows of pale yellow body spots on a brown background, small golden spots on the head, a sharp pointed tail, well developed pectoral fins, and the origin of the dorsal fin anterior to the gill opening. On the east coast of the United States this species has not been recorded north of the Cape Canaveral area (Gilmore 1977), although it also occurs in Bermuda, the Bahamas, Florida Keys, and the Caribbean (Böhlke and Chaplin 1968). This is one of the few eels regularly active in daytime (Böhlke and Chaplin 1968; Dubin 1982).

Holocentridae. Squirrelfish, observed from 30 to 98 m and most abundant from 52 to 98 m, were extremely common in association with rocks, holes, and burrows. They occured singly and in small schools.

Serranidae. Bank sea bass, *Centropristis ocyurus*, and black sea bass were both common from 23 to 34 m, but at greater depths, bank sea bass were more common (Table 1). Bank sea bass were generally sedentary and seemed to prefer the soft substrates immediately adjacent to the ledges, while black sea bass were broadly distributed over the reef. Graysby, *Epinephelus cruentatus*, first reported from North Carolina by Anderson *et al.* (1979), were common at one location (station 8) and were secluded everywhere they were observed. Single juvenile snowy grouper were observed several times occupying rock and burrow systems. Solitary snowy grouper were often seen resting on the upper portions of reefs at depths between 61 and 96 m. Below 116 m snowy grouper became more common, and at station 9 (125 to 137 m) over 100 were counted in one location over and around a pile of rocks. Red barbier usually appeared in large, fast-moving schools and occurred on all but one reef between 52 and 152 m. Most appeared to be juveniles <150 mm TL. Roughtongue bass, *Holanthias martinicensis*, occurred singly between 75 and 125 m, often in association with *Oculina* or *Madrepora* clumps. It occurred in North Carolina in shallower water than in Jamaica or British Honduras (150-200 m, Colin 1974), and it displayed the mid-body saddle described by Colin (1974). Wrasse bass were commonly observed on most reefs between 30 and 116 m and typically occurred singly under ledges, as reported by Shipp and Hopkins (1978). Gag and scamp were often seen together on reefs between 27 and 94 m, and they were the largest fish at most locations. Both species cruised just above and around the reefs, either singly or in groups of 2 or 3 (Fig. 5), except at station 4 where aggregations of 24 and 35 gag and 12 scamp were observed. Tattler occupied a habitat similar to that of bank sea bass, preferring to rest on the soft substrates surrounding reefs. Although one tattler was seen at 30 m, they were most common and occurred on every reef between 53 and 125 m.

Priacanthidae. Short bigeye and bigeye, *Priacanthus arenatus*, common on most reefs (27-116 m), usually hovered above cracks or near ledge overhangs, but short bigeye were more often associated with rocks and burrows (Fig. 6). They were never observed in schools and their stationary behavior suggested territoriality, as noted by Shipp and Hopkins (1978).

Lutjanidae. Vermilion snapper, the most common snapper, occurred between 58 and 116 m. Sightings were sporadic. On the night dive at station 7 we saw two individuals resting on the sand. The species is usually pelagic, probably feeds at night (Grimes 1979), and has not been reported as nocturnally inactive. Commercial fishermen report that feeding at night is sporadic (L.L. Davidson, pers. commun., Morehead City, NC 28557).

Sparidae. Red porgy were observed at 3 locations (stations 1, 9, 11). Hundreds of schooling juveniles occurred at station 1, up to 3 m above the reef. At station 9 (125 m) over 100 adults congregated on the bottom near the reef appeared to be feeding by rooting in the sand. Manooch (1977) reported that red porgy was predominately a benthic feeder. Six silk snapper seen with red porgy at station 9 exhibited the same rooting behavior.

Sciaenidae. Cubbyu, *Pareques umbrosus*, were abundant on several reefs in 23 to 91 m and occurred as deep as 116 m. They were usually associated with crevices and holes in rocky ledges, and large numbers were often crowded into small spaces (Fig. 8). large adults were dark colored like those Smith (1976) observed off western Florida. An undescribed species of *Pareques*, termed blackbar by George Miller (pers. commun., NMFS, Southeast Fisheries Center, Miami, FL 33149), was photographed at station 3 (94 m) and observed at stations 6 and 9 (94-125 m).

Chaetodontidae. Reef butterflyfish, *Chaetodon sedentarius*, the most common member of this family, seemed to prefer moderate relief areas between 52 and 98 m. On some reefs (particularly stations 4 and 11) they occurred in large, loose aggregations of as many as 20 to 30 individuals, but in other places they were seen singly or in pairs. Bank butterflyfish, *Chaetodon aya*, were seen frequently but usually at a greater depth (70 to 116 m) than other butterflyfishes, and usually singly on high profile areas.

Pomacanthidae. Rock beauty, *Holacanthus tricolor*, were previously thought to be rare off North Carolina like queen angelfish, *H. ciliaris*, and the two species of *Pomacanthus*. However, seven adult rock beauty were observed at station 13 (30 m) over very rocky substrate and one juvenile was observed on a ledge at 60 m (station 4). Our deepest sighting was at 85 m. Most rock beauty were observed at station 11 (58 m)

Figure 8. Cubbyu, *Pareques umbrosus*, (nearer camera) and squirrelfish, *Holocentrus ascensionis*, crowded into crevices and holes in rock outcropping.

as single or paired adults on and around a high ridge.

Pomacentridae. Yellowtail reeffish were common from 52 to 98 m. Shallower than 34 m they were scarce (except at station 13) and usually occurred as juveniles. Adults normally hovered about 1 m or less above the substrate, either singly (often associated with the rock and burrow structures) or in large aggregations. Solitary individuals appeared to be occupying territories. Purple reeffish, *Chromis scotti*, observed from 27 to 73 m, were more common on reefs shallower than 50 m and generally were closer to the substrate than yellowtail reeffish. Behavior of both species was similar to that described by Shipp and Hopkins (1978).

DISCUSSION

A major advantage of submersibles over surface deployed gear for estimating faunal composition of reefs is reduced survey time. We identified 99 species of fish at 13 locations during 23 h of observations over a 9 day period. In comparison, only 113 species, many identified from gut contents, were catalogued from collections made with traditional gear (mainly hook and line) at over 90 locations during 132 daily trips off the Carolinas (Grimes *et al.* 1982b). An extensive data base, covering a large proportion of North Carolina's reefs, indicates that there are at least 280 reef-related fishes in this area (Ross, in prep.). If this total could be considered a reasonable cumulative limit for North Carolina reefs, then the present study and that of Grimes *et al.* (1982b) identified 35% and 40% of the available ichthyofauna, respectively; however, the present study required much less survey time.

We agree with Uzmann *et al.* (1977) that observation of fishes over rough bottoms from a submersible in waters deeper than 34 m is superior to other techniques. SCUBA can be used adequately only in shallower water. Although both techniques may provide precise standing stock estimates, they preclude the collection of large numbers for food habits, aging, and other needs.

Surveys by rented, remotely operated vehicles are nearly as expensive ($5000 to $6000/day, with support vessel) as surveys by rented submersibles ($5000 to $10,000/day, with support vessel) and they have the same drawbacks as surveys by cameras. Powles and Barans (1980) found a trawl to be more effective than traps or television for obtaining reef fish data over very low profile (<30 cm) areas. Other studies off the Carolinas also identified problems with television transects for estimating faunal numbers and composition (South Atlantic OCS Study 1982). Although fish stock assessment from manned submersibles is expensive, it may be less expensive than estimates based on catches from traditional gear. The variability associated with the latter estimates can be unacceptably large. To reduce this variability, sample sizes and frequencies may have to be increased, resulting in more ship time and expense ($2,400/day for the R/V DAN MOORE (Cape Fear Technical College), $5,400/day for the R/V CAPE HATTERAS (Duke University)). On the other hand submersibles have the potential for obtaining estimates of population size and species composition with enough precision and speed so that fewer surveys are needed, thus reducing total cost.

Most of our observations were in the 52 to 98 m depth range, which has the greatest species richness and biomass. The greatest number of species recorded per station was also in this depth range (Table 2). The number of species observed and the duration of observations showed no consistent relationship (Table 2); in fact the number of species observed depended primarily on water clarity, amount of reef profile, and station water depth. Data from extensive trawling over reef areas off North Carolina by the R/V DAN MOORE indicate a rich zone that overlaps our most productive depth range (52-98 m) but extends to as shallow as 31 m (Ross, in preparation). Miller and Richards (1979) reported 33-40 m as the most productive zone for commercial reef fishes on the basis of trawl surveys in the South Atlantic Bight. Trawls, however, cannot adequately sample high profile reefs where species richness is highest regardless of depth. Reef fish community depth ranges, determined from analysis of 9,027 headboat trips off North and South Carolina and 122 research trips in Onslow Bay, N.C., were similar to the depth ranges we found (Chester *et al.* 1984).

Many species common in shallow southern waters were numerous only in greater depths off North Carolina. Colin (1974) reported a similar depth distribution in the Caribbean. Apparently such species as spotted moray, graysby, rock beauty, spotfin butterflyfish, sharpnose puffer, spotfin hogfish, *Bodianus pulchellus*, and blue tang, Acanthurus coeruleus, have a broad depth tolerance and can adjust to the most favorable depth (probably related to temperature) in a particular locality. However, these fishes do apparently have a depth limit near 100 m off North Carolina. Below this depth, speckled hind, snowy grouper, roughtongue bass, bank butterflyfish, and *Pareques sp.* (blackbar) consistently characterize the fauna, which is similar to the outer shelf fauna (>55 m) of Miller and Richards (1979).

Further research is planned to increase the precision and accuracy of estimates of reef fish abundance. One problem is determining the number of reefs to be sampled to estimate the mean number of fish per hectare within, for example, ±2 fish at the 80% confidence level. The most extensive and representative data we have is for the gag. From the variance (±33.4) about the mean number of gag per hectare (4.8) for seven selected stations, (we omitted the three deep water stations (6, 9, 10), since gag are rarely found in water deeper than 80 m; station 5, since counts and habitat were not matched; station 7, since the counts were at night, when fish behave differently than during the day; and station 12, since the sparse, low profile was not typical of gag habitat), we calculated that we would have to sample 14 reefs. This number may change as our data base expands during future surveys. These results will then be combined with surveys of the amount of reef habitat (Parker *et al.* 1983) to provide estimates of the total amount of reef fish important in the recreational and commercial catches. This information in turn will be used to estimate potential yield of these species.

ACKNOWLEDGMENTS

For help with the submersible and SCUBA fish count comparisons we thank divers Frank Chapman of the University of North Carolina in Wilmington, N.C., Bob Pentz of Wilmington; Jim Tyler of the North Carolina Division of Marine Fisheries, Morehead City, N.C., Glen Safrit of the University of North Carolina Institute of Marine Sciences, Morehead City, Mark Hooper and George Turner of Duke University Marine Laboratory, Beaufort, N.C., and Duncan Dawkins of the National Marine Fisheries Service, Southeast Fisheries Center, Beaufort. We also thank Bob Jones of the Harbor Branch Foundation, Inc., Ft. Pierce, FL., for reviewing the manuscript and making many helpful suggestions. This study could not have been done without the two submersibles, one provided by the Harbor Branch Foundation, Inc., Ft. Pierce and the other by NOAA's Man Undersea Science and Technology Office, Rockville, MD.

LITERATURE CITED

Alevizon, W.S., and M.G. Brooks. 1975. The comparative structure of two western Atlantic reef-fish assemblages. Bull. Mar. Sci. 25:482-490.

Anderson, H.M., T.H. Handsel, and D.G. Lindquist. 1979. Additional notes on tropical reef fishes in the Carolinas with zoogeographic considerations. (Abstr.) ASB (Assoc. Southeast. Biol.) Bull. 26(2):37.

Barans, C.A., and D.V. Holliday. 1983. A practical technique for assessing some snapper/grouper stocks. Bull. Mar. Sci. 33:176-181.

Böhlke, E.B., and S.W. Ross. 1981. The occurrence of *Muraena robusta* Osorio (Anguilliformes; Muraenidae) in the west Atlantic. Northeast Gulf Sci. 4:123-125.

Böhlke, J.E., and C.C.G. Chaplin. 1968. Fishes of the Bahamas and adjacent tropical waters. Livingston Publ. Co., Wynnewood, Pa. 771 p.

Bohnsack, J.A. 1982. Effects of piscivorous predator removal on coral reef fish community structure, p. 258-267. In: G.M. Calliet, and C.A. Simenstad (eds.), Gutshop' 81, fish food habits studies, proceedings of the Third Pacific Workshop. Wash. Sea Grant Publ. WSG-WO 82-2.

Bright, T.J., and L.H. Pequegnat. 1974. Biota of the West Flower Garden Bank. Gulf Publ. Co., Houston, Tex. 435 p.

Brock, V. 1954. A preliminary report on a method of estimating reef fish populations. J. Wildl. Manage. 18:297-308.

Chester, A.J., G.R. Huntsman, P.A. Tester, and C.S. Manooch, III. 1984. South Atlantic Bight reef fish communities as represented in hook-and-line catches. Bull. Mar. Sci. 34:267-279.

Colin, P.L. 1974. Observations and collection of deep-reef fishes off the coasts of Jamaica and British Honduras (Belize). Mar. Biol. (Berl.) 24:29-38.

__________. 1976. Observations of deep-reef fishes in the Tongue-of-the-Ocean, Bahamas. Bull. Mar. Sci. 26:603-605.

Collette, B.B., and F.H. Talbot. 1972. Activity patterns of coral reef fishes with emphasis on diurnal-nocturnal changeover. Nat. Hist. Mus. Los Ang. Cty. Sci. Bull. 14:98-124.

Dubin, R.E. 1982. Behavioral interaction between Caribbean reef fish and eels (Muraenidae and Ophichthidae). Copeia 1982 :229-232.

Ebeling, A.W., R.J. Larson, W.S. Alevizon, and R.W. Bray. 1980. Annual variability of reef-fish assemblages in kelp forests off Santa Barbara, California. Fish. Bull., U.S.78:361-377.

Emery, A.R. 1973. Comparative ecology and functional osteology of fourteen species of damselfish (Pisces: Pomacentridae) at Alligator Reef, Florida Keys. Bull. Mar. Sci. 23:649-770.

Fike, J.W., and R.B. Dolan. 1976. A submersible diving system for science. Pap. Annu. Offshore Technol. Conf. 8 (2574):529-538.

Gilmore, R.G., Jr. 1977. Fishes of the Indian River lagoon and adjacent waters, Florida. Bull. Fla. State Mus. Biol. Sci. 22(3):101-148.

Grimes, C.B. 1979. Diet and feeding ecology of the vermilion snapper, *Rhomboplites aurorubens* (Cuvier) from

North Carolina and South Carolina waters. Bull. Mar. Sci. 29:53-61.

___________, K.W. Able, and S.C. Turner. 1982a. Direct observations from a submersible vessel of commercial longlines for tilefish. Trans. Am. Fish. Soc. 111:94-98.

___________, C.S. Manooch, and G.R. Huntsman. 1982b. Reef and rock outcropping fishes of the outer continental shelf of North Carolina and South Carolina, and ecological notes on the red porgy and vermilion snapper. Bull. Mar. Sci. 32:277-289.

Hastings. R.W. 1979. The origin and seasonality of the fish fauna on a new jetty in the northeastern Gulf of Mexico. Bull. Fla. State Mus. Biol. Sci. 24(1):1-122.

___________, L.H. Ogren, and M.T. Mabry. 1976. Observations on the fish fauna associated with offshore platforms in the northeastern Gulf of Mexico. Fish. Bull., U.S. 74:387-402.

Helfman, G.S. 1983. Underwater methods, p. 349-369. *In*: L.A. Nielsen and D.L. Johnson, (eds). Fisheries techniques. American Fisheries Society, Bethesda, MD.

Huntsman, G.R. 1976. Offshore headboat fishing in North Carolina and South Carolina. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 38(3):13-23.

Jones, R.S., and M.J. Thomson. 1978. Comparison of Florida reef assemblages using a rapid visual technique. Bull. Mar. Sci. 28:159-172.

Luckhurst, B.E., and K. Luckhurst. 1978. Diurnal space utilization in coral reef fish communities. Mar. Biol. (Berl.) 49:325-332.

Manooch, C.S., III. 1977. Foods of the red porgy, *Pagrus pagrus* Linnaeus (Pisces: Sparidae), from North Carolina and South Carolina. Bull. Mar. Sci. 27:776-787.

Miller, G.C., and W.J. Richards. 1979. Reef fish habitat, faunal assemblages, and factors determining distributions in the South Atlantic Bight. Proc. Gulf Caribb. Fish. Inst. 32:114-130.

Parker, R.O., Jr., D.R. Colby, and T.D. Willis. 1983. Estimated amount of reef habitat on a portion of the U.S. Atlantic and Gulf of Mexico continental shelf. Bull. Mar. Sci. 33:935-940.

___________, R.B. Stone, and C.C. Buchanan. 1979. Artificial reefs off Murrells Inlet, South Carolina. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 41(9):12-24.

Powles, H., and C.A. Barans. 1980. Groundfish monitoring in sponge-coral areas off the southeastern United States. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 42(5):21-35.

Reed, J.R., and R.G. Gilmore. 1981. Inshore occurrence and nuptial behavior of the roughtail stingray, *Dasyatis centroura* (Dasyatidae), on the continental shelf, east central Florida. Northeast Gulf Sci. 5:59-62.

Ross, S.W. (in preparation). Distribution and composition of the North Carolina reef ichthyofauna. North Carolina Division of Marine Fisheries, Morehead City, NC 28557.

Shipp, R.L., and T.S. Hopkins. 1978. Physical and biological observations of the northern rim of the De Soto Canyon made from a research submersible. Northeast Gulf Sci. 2:113-121.

Smith, C.L., and J.C. Tyler. 1973a. Direct observations of resource sharing in coral reef fish. Helgol. Wiss. Meersunters. 24:264-275.

___________. 1973b. Population ecology of a Bahamian suprabenthic shore fish assemblage. Am. Mus. Novit. 2428:1-38.

Smith, G.B. 1976. Ecology and distribution of eastern Gulf of Mexico reef fishes. Fla. Mar. Res. Publ. 19, 78 p.

South Atlantic OCS area living marine

resources study, year II. 1982. Final report. Prepared for Minerals Management Service, Washington, D.C. under Contract AA551-CT1-18 by Marine Resources Research Institute, S.C. Wildlife and Marine Resources Department, Charleston and Duke University Marine Laboratory, Beaufort, N.C. 2 vols.

Starck, W.A., II. 1968. A list of the fishes of Alligator Reef, Florida, with comments on the nature of the Florida reef fish fauna. Undersea Biol. 1:5-40.

Uzmann, J.R., R.A. Cooper, R.B. Theroux, and R.L. Wigley. 1977. Synoptic comparison of three sampling techniques for estimating abundance and distribution of selected megafauna: Submersible vs. camera sled vs. otter trawl. U.S. Natl. Mar. Fish. Serv., Mar. Fish. Rev. 39/12):11-19.

Wenner, C. 1983. Species associations and day-night variability of trawl-caught fishes from the inshore sponge-coral habitat, South Atlantic Bight. Fish. Bull., U.S. 80(3):537-552.

Willan, R.C., J.M. Dollimore, and J. Nicholson. 1979. A survey of fish populations at Karikari Peninsula, Northland, by scuba diving. N.Z. J. Mar. and Freshwater Res. 13(3):447-458.